Design and Construction of a GSM-Based Smart Electricity Billing System

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Abstract— This work presents a GSM Based Electric Billing System aimed at accomplishing optimal control of energy consumption using a microcontroller (PIC16f877A) and a GSM Module (SIM800). The developed electric power controller consists of both the hardware and software aspects. The hardware aspect consists of the power supply section, the sensor unit, the logic control unit developed by the use of the PIC16f877A microcontroller, the transceiver unit developed using the phone station and SIM800, the switching unit, and the display unit. The software aspect was achieved using a code in C language. The entire system was then integrated into one functional unit and first simulated to ensure that expected results are obtained before a successful implementation of a prototype.

Index Terms— Microcontroller, GSM Module, Smart Meter, Electricity Billing

1 Introduction

An efficient electric system is one of the most important characteristics of developed nations world-wide. Every organization, whether in the public or private sector, cannot function without efficient power supply. With the increase in population as years pass by, the demand for electricity is on the increase. Electricity generation and conveyance is capital-intensive hence the need for accurate billing to ensure that the power companies break even. Until recently in Nigeria, the billing system appears to encourage the over-billing or deliberate cheating of electricity consumers. This has resulted to rampant power theft and attendant sundry commercial losses [1], [2], [3], [4]. The above narrative aggregated in the introduction of electronic energy meters in the Nigeria electricity industry by the National Electricity Regulatory Commission (NERC) [5].

The initial electronic meters, made electricity consumption convenient to some extent. It eliminated estimated billing and the security challenge associated with door-to-door visit by power employees of electricity distribution companies. It also made purchase of power unit very easy and within reach. A variant of the electronic meters use buzzers to alert the customer when the remaining power unit is low while another variant makes no communication whatsoever with the customer as available power reduces. These are major drawbacks of existing commercially-available models.

The current work on GSM-Based Smart Electricity Billing System, rather than using a buzzer to alert consumers, utilizes GSM module (SIM 800) to send messages to the consumers, informing them of much power unit remaining as well as other information concerning the meter. This is more convenient for the customers [6], [7].

This objective is achieved with GSM application, current and voltage sensors which senses energy and follows it up until it is just about to be used up. Thus, optimal control of the current flow at various homes, industries and anywhere electricity is needed is achieved. Hence this project has two-fold objective: incorporating the sensing of current flow and energy consumption and the use of GSM application to control the purchase and usage of energy [8].

2 Description and Working of the Smart Meter

This work is divided into six-sections as shown in the block diagram of Figure 1. These include, the power supply unit, the sensor unit, the control unit, the transcerver unit, the switching unit and the display unit.

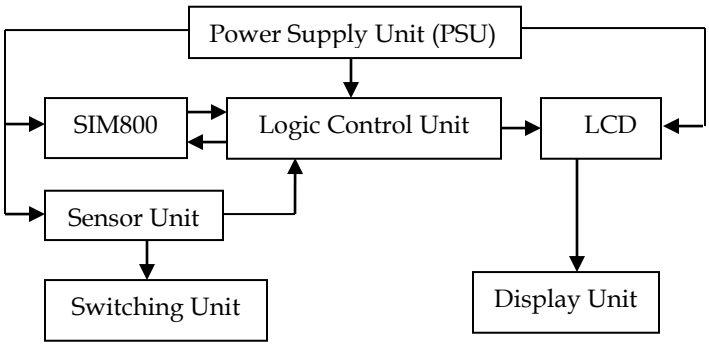

Fig. 1: System Block Diagram

2.1 The Power Supply Unit

This is made up of a 12V step down transformer, a bridge

rectifier, a capacitor, a 7805-voltage regulator. The transformer steps down 220V AC to 12V AC which is used to power the relay. The bridge rectifier converts the 12V AC to 12V DC. The Capacitor filters-off ripples from the supply and 7805 voltage regulator pegs the 12V DC to 5V DC which is used to power the LCD, microcontroller, SIM800 and ACS712.

2.2 The Sensor Unit

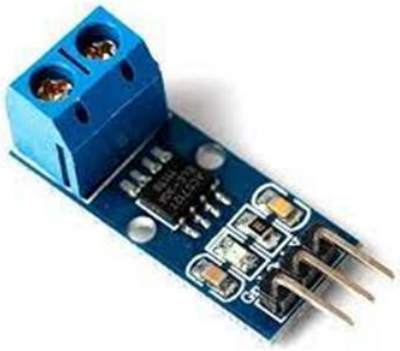

Fig. 2: ACS712 Current Sensor

This is made up of bridge rectifier, capacitor, voltage divider network of two resistors (220k and 5k) and ACS712 current sensor. The bridge rectifier is used to convert 220V AC to 218.6V DC. There was 1.4V drop across the diodes. The capacitor is used to filter off ripples from the source. The voltage divider network forms voltage sensor. It scales the 218.6V DC to 5V DC. Its output is connected to ADC channel 0 of microcontroller. ADC converts the analog signal to digital form. Software is then used to scale up the voltage and measure it accordingly. ACS712 is a current sensor. Its output is connected to ADC channel 1 of the microcontroller. Software is then used to determine the amount of current flowing through the load. Multiplying voltage and current, we have power. And multiplying power with duration/time of usage, we have energy in kWh. Timer of microcontroller was used to capture time.

2.3 The Control Unit

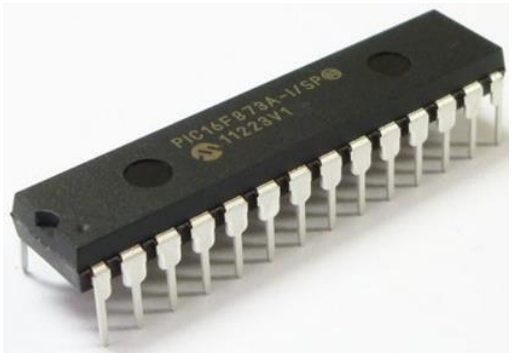

Fig. 3: PIC16f873A microcontroller

This is made up of PIC16f873A microcontroller. It was programmed in C language to achieve the following:

i. Identify when there is power on the line
ii. Measure voltage and current with sensors and calculate power and energy consumption from obtained values.
iii. Communicate to user through SIM800 GPRS/GSM module.
iv. Switch power on or off depending on user's available units.
v. Provide the LCD with information to display.

2.4 The Transceiver Unit

Fig. 4: SIM800L GPRS/GSM Module

This is made up of two sub units:
i. Phone station
ii. SIM800 GPRS/GSM module.

Phone station is transceiver unit because it can transmit to SIM800. It can send airtime and commands to it and can receive message from it. SIM800 station is a transceiver unit too because it can send messages to phone station and can receive airtime and commands from it. SIM800 is a GPRS/GSM module. It has SIM card in it and can be used to make calls, receive and send messages. In this application, we are using it to send messages to the user, informing them him of much unit that remains in his meter and also to provide other information about the meter.

2.5 The Switching Unit

This is made up of 100Ω resistor, BC547 NPN transistor, IN4007 diode and 12V DC relay. The 100Ω resistor is used to limit the amount of current flowing through the transistor in order to protect it. The transistor drives the relay by amplifying the voltage supply to it. The IN4007 diode, in this application, is a freewheeling diode connected in reverse bias and used for preventing the energy stored in the relay coil from damaging the components around the relay. The relay is used for switching load on or off depending on user's available unit.

2.6 The Display Unit

This is made up of 16 x 2 LCD. This has 16 columns and two rows. It can accommodate 32 characters at once. It displays information about the system, such as voltage, current, power, energy, on/off state, etc.

2.7 The Power Management and Measurement

This Energy Meter is an intelligent device that takes record of the power consumed by loads connected to it. It connects the loads to the distribution lines. The microcontroller together with the sensors follows up the consumption of power until the purchased units is used up.

Recharging the GSM module from the phone station is the way of purchasing power with this Energy Meter. Once there is airtime in the GSM module with the help of the Sim Card embedded it the GSM module, the loads connected to the Energy Meter would have access to power. The timer of the microcontroller is used to capture time in seconds, the current Sensors measures current in amperes and the voltage sensor gives us the voltage in volts and the C Programme is used to obtain the product of the three and convert the units to kWh.

This meter is designed to inform its user when his account is recharged and when his purchased unit is about to be used-up with the help of the GSM module and the users phone number programmed into the microcontroller using SMS as its tool.

3 Design Methodology and Testing

The complete circuit of the system shown in figure 2 was designed and successfully simulated in Proteus 8.1 environment. The component selection and initialization in Proteus is as already reported in [9], [10], [11]. This is followed by hardware implementation to realize the prototype. The sub-circuits of the system are already explained in the sub-sections. The prototype and test result is as shown in section 3.1.

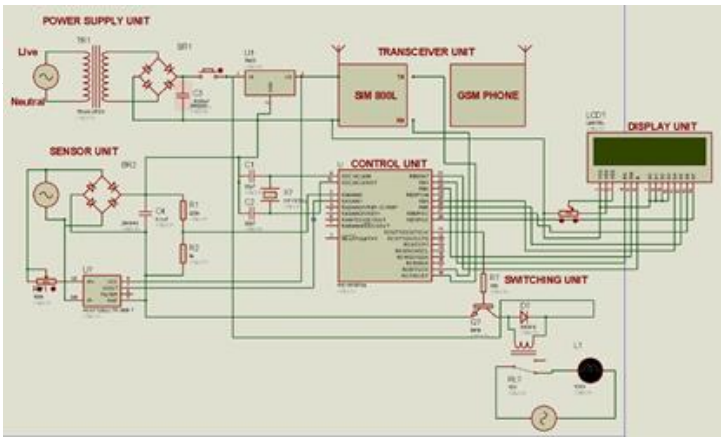

Fig. 5: Complete System Circuit Diagram

3.1 Testing

A test was carried out and the test circuits are shown in Figures 6, 7 and 8. The design worked as expected.

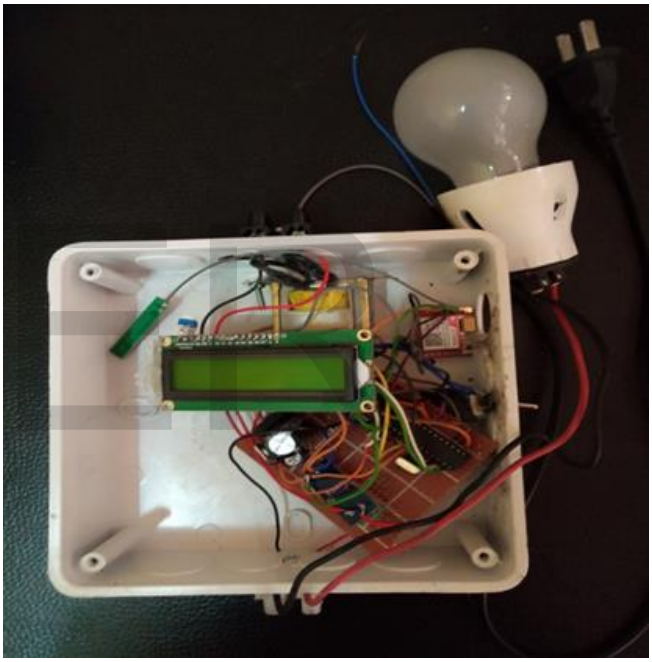

Fig. 6: Internal Circuitry of the System

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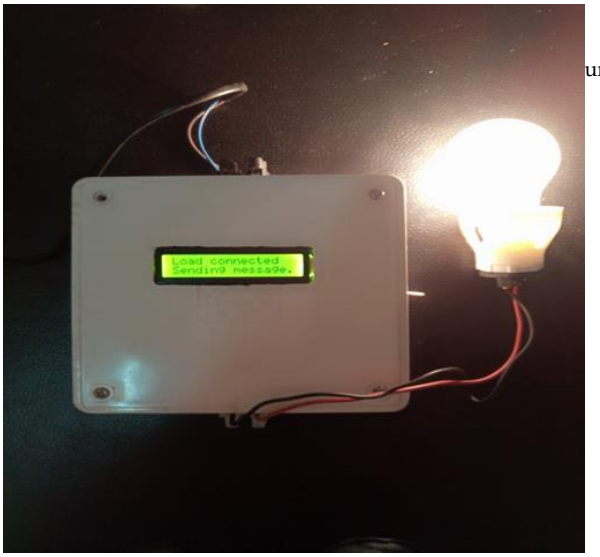

Fig. 7: The System in Working Condition

Fig. 8: Current, Voltage, Power and kWh Reading

4 Conclusion

This Paper presents the idea of the Energy Meter as the controlling and managing unit of the utilities. It shows how this system is beneficial to everyone especially invalids and also to distribution companies of countries that work under a single umbrella. However, customers will never suffer due to any unwanted condition and the system will justify customer requirement.

For further enhancement, this paper may bring a power revolution in communication market by the collaboration of power sector and communication sector so that a customer will have all the facilities from one vendor.

This paper presents recommendation to government officials related to power especially the minister of power, works and housing of Nigeria so that importation of energy meters into Nigeria would decrease drastically and in return save revenue used in importing these meters and with much development of this project quality wise, Nigeria can also be part of the countries exporting smart energy meters.

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